Review of Stormwater Manual - Sand Filtration Basins for Department of Ecology, State of Washington

Prepared by

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Introduction

The Department of Ecology (ECS), State of Washington, is in the process of finishing a "Stormwater Manual" for western Washington. In response to the request of Megan White, P.E. and Stan Ciuba, Manager and Senior Staff of Water Quality Program, ECS, respectively, this report is to provide comments and recommendations for this manual, specifically for the Sections of Sand Filtration, Volume 5, Stormwater Manual.

George C. Chang, a Principal of CAS Consulting and Services, Inc. has substantial experience in the design, construction, maintenance, and performance monitoring of sand filtration basins (see copy of Chang's resume). Chang has made efforts to review the subject Sections, including 5.3 - Sand Filtration, 5.5 - Sand Filtration Basins, 5.6 - Sand Filter Vaults, and 5.7 - Linear Sand Filters. This review also includes comments from the colleagues of CAS and a study of some key references.

Objectives of Guideline and Review

The Stormwater Manual of ECS presents criteria or guidelines for the planning, design, construction, and maintenance of runoff treatment sand filters. The objective of the sand filtration guidelines is to control the quality of stormwater from new development or redevelopment areas such that the water quality of effluent from sand filters can comply with specific standards or goals. These goals are to expect achieving average pollutant removals as follows:

For basic sand filter:

- 80% TSS at typical influent concentrations of 30-100 mg/l.
- Oil and grease to below 10 mg/l daily average and 15 mg/l at any time, with no ongoing or recurring visible sheen in the discharge.

For large sand filter:

- At least 50% of the phosphorous compounds (as P).

The objective of this review is to confirm the adequacy of the subject guidelines, including its accuracy, completeness, and clarity. This review should include comments and recommendations pertaining to the applications, performance expectations, design, construction, and maintenance criteria, and future research needs that are essential for installing, operating, and maintaining sand filters for stormwater treatment.

Description of Findings

I. <u>Applications</u> (Refer to Section 5.3)

Comments: Sand filtration has been widely used in Austin, Texas for years in residential subdivisions, and commercial and industrial sites. Nevertheless, sand filter has rarely been used in sites with an effective impervious area greater than 60 acres. It is impractical to design and construct a huge, on-site sand filtration basin in considering its high cost and maintenance difficulties. For sand filter vaults and linear sand filters, it is quantitatively difficult to construct and maintain a sand filtration basin that can treat drainage from an effective impervious area of greater than 2 acres.

TAC

Recommendations: Specific applications should include single-family residential subdivisions of various sizes. Sand filtration applications should be limited to a drainage equivalent to runoff from an impervious area of less than 60 acres. Filter vaults and linear filters should be limited to a drainage equivalent to runoff from an impervious area of less than 2 acres.

II. Performance Expectations (Refer Sections 5.3, 5.6. &5.7)

Comments: Recent monitoring data (References 1-5) indicate that sand filters are effective on removal of total suspended solid (TSS), oil and grease (O&G), and total phosphorous (TP). Performance expectations specified in the "ECS guidelines" pertaining to TSS, O&G, and TP are generally adequate. Nevertheless, these goals may not be clearly specified. The 80% removal of TSS should only refer to flows passing through the sand filtration basin. In other words, a sand filter treats only a portion of runoff (i.e., ½-inch) that passes through the sand bed. The remaining portion of runoff is diverted to other place such as the creek or a floodwater detention basin; otherwise runoff overflows over the sand bed surface. The annual or average removal efficiency for the filter can be determined by estimating the percent reductions of loads or EMCs for individual storms. The Austin, Texas data (references 1-2) show that the outflow event mean concentration (EMC) values of TSS, TP, and some other pollutants are generally proportional to those of the influent EMCs. This indicates that the rate of removal for a range of influent EMC values is roughly a constant. For TSS, the Austin data show a wide variation of influent EMC values, ranging from 50 mg/l to 750 mg/l. The 30-100 mg/l range specified in page 2 of the "guidelines" is somehow too small.

Ed?

Add this!

Recommendations: Performance expectations can be better stated, for example, "Sand filters treat runoff passing through its presettling chamber and sand bed. On the average (or on the annual basis), sand filters (including basic, vault, and linear filters) are expected to achieve the following pollutant removals: 80% TSS at influent EMCs of 30-300 mg/l, and 40% TP at influent EMCs of 0.15-1.00 mg/l. A large sand filter can remove at least 50% of TP. No change is recommended for oil and grease.

Ed?

OK NO

III. Design Criteria (Refer to all Sections)

Comments: A flow splitter or diversion structure is an integrated part of the sand filtration system. A sand filter usually treats the first ½-inch runoff (or specific amount of runoff from a design storm) from a site and diverts the remaining water to the downstream side. The excessive runoff, if not diverted off from the system, would otherwise disturb storage of both sedimentation and sand filtration basin and thus impact the overall removal efficiency. This diversion structure is not or not clearly identified in the text and in some of the drawings of the subject "guidelines" (Figures 5-10, 5-14, 5-16, and 5-19~21 of the ECS guidelines). For runoff entering the filter system, it is mainly treated by the sand bed and the success of treatment generally depends on the rate of flow passing through the sand. Flow through rate for sand filter is a function of four factors, hydraulic head above the sand bed, sand bed area, hydraulic conductivity, and materials accumulated on and within the filter.

ok

In this connection, Darcy's law should be the key equation for designing sand filtration system. The hydraulic conductivity (k) is a constant for a specific type of sand but it decreases with time following the implementation of the sand filter, due to accumulation of sediment on the surface of sand bed (Reference 7). The k-value should gradually approach to a constant that is much lower than its original value. The monitoring of Barton Ridge Pond (Reference 1), a large sand filter, indicates that the average k-value during a 9-month operation in 1995 is about 2.5 inches per hour. This value was estimated to be just above 1 inch/hour at the end of operation. The guideline's proposal of 1 inch/hour for basic sand filter is generally appropriate. This value and the water quality volume (i.e., the designed volume of runoff entering sand filtration system) are key information for sizing the sand filter system, i.e., the sand bed and the presettling chamber. This "guidelines", however, has not provided an example on how to size the sand filter system. OK, added

Also, the description about sand filters is somehow confusing, although the contents of the guidelines are generally adequate. The variation or classification of sand filters is not clearly stated. The drawings are not adequately presented in accordance with the description.

Recommendations: Following is some proposed changes concerning the description.

- A basic sand filtration system shall consist of a flow splitter or diversion structure, flow spreader(s) (for spreading flow into sedimentation chamber and/or sand filtration basin), a sand bed or sand filtration basin, and the under-drain piping system. In most cases, this filtration system shall have a sedimentation or presettling chamber (Figures 5.10~11) (or Figures 5.16 in the "guidelines"). OK will change
- The variation of a basic sand filtration includes, but not limited to, large sand filter (Figure 5.12) (or Figure 5.11 in the "guidelines"), sand filter with level spreader (Figure 5.13) (or Figure 5.14 in the "guidelines"), sand filter vault, and linear sand filter (Figures 5.19 & 5.20) (or Figures 5.19~5.21 in the "guidelines"). OK, changed per Cheng
- ok All sand filters should have a flow splitter or diversion structure that diverts excessive runoff to the downstream creek or detention. This structure should be specified in some drawings of the "guidelines" (see "marks" in these drawings).
- ok Examples of diversion/flow splitter structure are shown in Figures 5.14 and 5.15 (or Figures 5.12 and 5.13 in the "guidelines").
- ok Flow spreader and/or flow control device are identified in Figures 5.11, 5.13, 5.14, 5.16, and 5.19 (or Figures 5.16, 5.14, 5.12, and 5.20 in the "guidelines").
- Sand bed systems or sand filtration basins are shown in Figures 5.17 and 5.18. ok
- A sample computation or some equations should be provided to demonstrate how the sand filtration system is sized, including the determinations of sand bed surface area and volumes of sedimentation and sand filtration chambers ok
- For basic sand filter, filter vault, linear filter, and large filter placed in heavy-use areas, using a k-value of one inch per hour is generally adequate. For large sand filters placed in lighter sedimentation area (where the mean TSS EMC is less than 150 mg/l), a greater k-value of 1.50 inch/hour is applicable. ok proposed for Chen & TAC

? propose Kim Co. approach to TAC

IV. Criteria Pertaining to Construction and Maintenance (Refer to all Sections)

Comments: A sedimentation or presettling chamber plays an important role in the operation of a sand filtration system. The sedimentation chamber retains debris, gross solids, and large particulate matters, and reduces velocity of flow to the sand filtration basin. In order to avoid costly repair to the filtration basin, the sedimentation chamber is subject to more frequent maintenance. A large sedimentation chamber with easy road access is often a necessity for sand filtration. An impermeable liner is also an important part of the sand filtration system. The Austin, Texas data (Reference 2) indicate that without an adequate liner, up to 20 percent of water entering the sand filtration system can be lost to percolation. This portion of water percolated into ground is not treated by the filtration system and may be subject to unexpected problems. An impermeable liner should be required for all sand filtration applications.

As mentioned before, a flow splitter or diversion structure is an integrated part of the sand filtration system. A linear sand filter provides no such structure and should be further evaluated. A berm or gabion structure was often used as a filter or flow spreader for sand filtration basin. These structures, however, can be easily clogged and require substantial maintenance. Maintenance for a sand filtration system is essential for its normal operation. It is often necessary to have an enforceable maintenance program at the time of construction. Safety and vandalism concerns are also important considerations in constructing a sand filtration system.

Recommendations: Following is proposed changes or additions to the text.

- Presettling chamber should be constructed as large as possible. Easy access to the presettling chamber is essential for frequent cleaning.
- Impermeable liner is always necessary for basic and large sand filters. ?
- A third chamber parallel to sediment chamber should be added to the linear sand filter and be used as a flow splitter or diversion structure. If the third chamber is not constructed, then the sand filter should be applied to a very small drainage area such that it can catch all runoff from this area without any overflow. OK
- A berm or gabion structure should not be used for passing runoff from the sediment chamber to the sand filtration basin unless there is an access for maintenance vehicles to approach the structure.
- An enforceable maintenance agreement is required at the time of a permit being issued for construction.
- Safety and vandalism prevention measures should be specified in the construction plans.

Proposal for Future Research

Sand filtration has been used to treat urban runoff for the past 20 years. Many of sand filters failed to operate as expected. Previous monitoring results indicate that those with better design and maintenance effort can effectively detain runoff pollutants without significant problems. Innovative designs are still a goal in sand filtration applications. People are interested in sand filters that cost less, taking less space, and requiring less maintenance efforts.

One highway project in Austin (Reference 3), Texas proposed the so-called vertical sand filter that required less filtration area and provided access to vehicles for maintenance. The test on vertical sand filters shows that the systems present some problems. The filter could not pass runoff water because of a low hydraulic head and the often-clogged gabion and sand structure. Nevertheless, the project provided much information on the design and maintenance of a sand filtration system. In this regard the reviewer is proposing the following for future research in sand filter application.

- Establish and organize database of sand filtration from various monitoring operations. Existing data is abundant and this data is important in enhancing sand filtration applications.
- Pursue innovated design on sand filtration basins that provide better treatment and better access for maintenance.
- Continue monitoring projects in specific areas such as more testing on small sand filters (vaults and linear filters) and better quantification of "hydraulic conductivity" when the sand bed is operative but saturated with sediment loads.

Specific Comments and Recommendations

This review has marked specific comments and proposed changes on the original "guidelines." For drawings, the review also proposed changes and marked on the hard copies of the corresponding drawings. An electronic copy and a hard copy of the "guidelines" are enclosed with this review (see Attachments 1-2).

References of Review

1. City of Austin, "Evaluation of Nonpoint Source Controls, An EPA/TNRCC Section 319 Grant Report," Vol. 1, Final Report, Watershed Protection Department, December 1997.
2. City of Austin, "Enhanced Roadway Runoff Best Management Practices," Prepared by Barton Springs/Edwards Aquifer Conservation District and the City of Austin, November 2000.
3. City of Austin, "Removal Efficiencies of Stormwater Control Structures," Watershed Protection Department, May 1990.
4. City of Austin, "Environmental Criteria Manual, " Sections 1.6~1.10, Design Guidelines for Water Quality Control, June 1988, Updated 1994.
5. City of Alexandria, "Assessment of the Pollutant Removal Efficiencies of Delaware Sand Filter BMPs, Draft," Department of Transportation and Environmental Services, March 1995.
6. Denver Urban Drainage and Flood Control District, " Design of a Sand Filter for Stormwater Quality Enhancement, Draft" Prepared by Ben R. Urbonas, Master Planning and South Platte River Program, July 1997.
7. The Center for Watershed Protection, "Design of Stormwater Filtering Systems," Prepared for Chesapeake Research Consortium by Richard A Claytor and Thomas R. Schueler, December 1996.

Attachment 1. Original Guidelines (with Marked Comments)
(Both hard and electronic copies)

Attachment 2. Original Drawings (with Proposed Changes)

Attachment 3. Copy of Resume

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George C. Chang, P.E.

Summary

Ph.D. in engineering; over 30 years of diversified experience, including water resource engineering, environmental studies, wastewater facility planning and design, and related field operation activities.

- Planned, implemented, and operated engineering, environmental and data service programs. Led the activities of various professional and field operation teams.
- Proposed, prepared, and/or managed numerous grants, service contracts, and inter-local agreements.
- Authored and published about 40 reports, research papers, and design criteria manuals on hydrology, watershed study, and sand filtration.
- Reviewed and analyzed design and construction plans pertaining to water, wastewater, and land development projects.
- Supervised the planning and design of regional wastewater facilities and various hydraulic structures related to water resource projects.

Major Projects

- Projects manager or co-manager for watershed "Best Management Practice (BMP)" projects, City of Austin (1981-1999). Projects included planning, design, operation, and monitoring of various types of storm water control basins such as Barton Ridge Plaza detention/filtration pond system, St. Elmo Retention Pond, Loop 1 Highway Runoff detention and filtration ponds, and various types of sand filtration basins. These new or retrofit projects were designated to improve storm water runoff quality and satisfy flood control requirements.
- Project manager for Waller Creek Watershed Retrofit Study, City of Austin (1994-1996). Directed the planning, design, monitoring, and computer simulation of a 5.4 square mile watershed system. Project was to evaluate alternative plans of a structure network (including flood control reservoirs, channel sections, and water quality control basins) in the watershed. Total project cost was about $300,000.
- Program manager for storm water runoff monitoring projects, City of Austin. Led the planning, design, field operation, and report preparation for a large-scale monitoring and modeling program. Program had more than 100-storm water, stream flow, and BMP monitoring stations. Total cost for the program was about $10 millions for 8 years (1992-1999).
- One of the principal authors for the City of Austin's Environmental Criteria Manual which includes design guidelines for erosion and sedimentation control devices, and detention and water quality control basins (1986-1991).
- Project engineer for design and design analysis of area-wide wastewater treatment plans, Texas Water Development Board. Project included the planning, design, and management of Killeen-Temple area wastewater treatment facilities (1977-1980).

Education

Mississippi State University, Mississippi State, Mississippi
- Ph.D., Water Resource Engineering, with minor in statistics, 1970
- M.S., Hydrology and Hydraulics, with minor in statistics, 1967

National Taiwan University, Taipei, Taiwan
- B.S., Engineering, 1961

Memberships and Activities

- Member, American Society of Civil Engineers
- Member, American Statistical Association
- Member (1997-1999), Editorial Board, "Techniques," Center for Watershed Protection, Silver Spring, Maryland
- Chair (1995-1999), Best Management Practices, Statewide Storm Water Task Force, American Public Works Association, Texas Chapter
- Program Leader to receive EPA 's National Environmental Excellence Awards in 1993 and 1996

Experience

CAS Consulting and Services, Inc.
1999-Present, Principal

- Performed reservoir and streamflow studies for the State of Texas' "Water Availability Modeling Projects."
- Conducted construction management services for a commercial site development project.

City of Austin
1992-99, Manager, Monitoring Section, Watershed Protection Department
1986-91, Data Analysis Manager, Environmental Services Department
1980-85, Chief, Water Quality Unit, Public Works Department,

- Developed and administered section and program budget; supervised activities of teams of engineering, data service, and field operation.
- Managed contracts or cooperative programs for professional services; supervised state and federal grant projects.
- Supervised a large-scale, storm water runoff-monitoring program.
- Monitored and evaluated the impacts of land development projects and proposed pollution control strategy alternatives.
- Administered "National Pollutant Discharge Elimination System (NPDES) Municipal Permit Application" project.
- Authored or co-authored engineering manuals.
- Co-managed a residential water conservation project. Performed data analysis and authored report for the project.
- Led a modeling study of Barton Creek, Austin, Texas, including watershed modeling using Storm Water Management Model (SWMM)
- Supervised the design and construction of various hydraulic structures.

Texas Department of Water Resources
Engineer II – Engineer IV, Texas Water Rights Commission, 1970-1977
Engineer IV, Texas Water Development Board (TWDB), 1977-1980

- Conducted hydrologic and water quality studies for Texas river basins, and bays and estuaries using TWDB's hydrodynamic and basin simulation computer models.
- Designed and analyzed design of regional wastewater facilities.
- Performed design analyses of dams, spillways, and open channels for water use permit reviews.
- Initiated and developed a large-scale computer model for appropriation of water to users in accordance with the priority of water rights.

CHAPTER 5 -- Infiltration/Bioinfiltration/Filtration Treatment BMPs

5.3 Sand Filtration BMPs

Introduction

This section of Chapter 5 presents criteria for the evaluation, design, construction and maintenance of runoff treatment sand filters including basin, vault, and linear filters. The use of sand filtration to treat storm water runoff was initiated during the 1980s by the City of Austin, Texas.

Purpose of Sand Filtration BMPs

To remove TSS, organics, phosphorous, and insoluble oils from stormwater.

for spreaders flow into sand filter

Description

A typical sand filtration system consists of a flow splitter or diversion structure, a pretreatment system, ~~a water storage reservoir~~, flow spreader(s), a sand bed, and the underdrain piping. A basin liner may also be needed if the treated runoff is not to be allowed to percolate into the soil underlying the filtration basin. For instance, a liner would be necessary if the filtered runoff required additional treatment, such as in a wet pond for further nutrient removal, or in cases where additional ground water protection was mandated. Figures 5.10 and 5.11 provide examples of "basic sand filtration basin systems" in use. The variation of a basic sand filter includes large sand filter, sand filter with level spreader, ---- sand filter vault and linear sand filter ~~(see Description of Findings in the "review document")~~.

Performance Objectives

Basic sand filter: On the average ~~(or annual basis)~~, Basic sand filters are expected to achieve the following pollutant removals: 80% TSS at influent EMCs of 30-300 mg/L, 50% ~~40%~~ TP, and oil and grease to below 10 mg/L daily average and 15 mg/L at any time, with no ongoing or recurring visible sheen in the discharge. See Ch. 4.

Large Sand filter: To remove at least 50% of the total phosphorous compounds (as TP). (4)

Applications And Limitations

Sand filtration can be used in most residential, commercial, and industrial developments where heavy sediment loads and debris, such as oils and greases from fast food restaurants, will not clog or prematurely overload the sand. Specific applications include residential subdivisions, parking lots for commercial and industrial establishments, gas stations, high-use sites, high-density multi family housing, roadways, and bridge decks. Sand filters should be located off-line ~~as possible~~. Linear sand filters may be used on-line for oil control at high-use or similar sites.

Sand filters are suited for locations with space constraints in retrofit, and new/re-development situations. Overflow or bypass structures must be carefully designed to handle the larger storms. An offline system generally treats the first ½-inch runoff or specific volume of runoff from a designed storm, and diverts the remaining inflows to the downstream creek or detention.

Consider pretreatment to reduce velocity to sand filtration basin, and remove oils, debris, floatables, solids, and large particulate matters. Filtration should not be considered in high water table areas. Consider an underground filter in areas subject to freezing conditions. (8)

Site Suitability

The following site characteristics should be considered in locating a media filtration system:

- Space availability, including presettling basins
- Sufficient hydraulic head, at least 4 feet from inlet to outlet
- Adequate Operation and Maintenance capability
- Sufficient source control including reductions of debris and solids.
- Acceptable capital and annual costs

Design Criteria For Sand Filter BMPs

Flow through sand filtration basin (sand bed) should be designed using Darcy's Law. This approach and other pertinent design criteria are discussed below.

$$Q = k * i * A_s$$

Where Q is the flow rate at which runoff is filtered by the BMP, k is the hydraulic conductivity, i is the hydraulic gradient, and A_s is the filtration bed surface area.

The hydraulic gradient is given by the equation:

$$i = \frac{h + L}{L}$$

where h is the average height of the water column over the top of the sand bed and L is the thickness of the sand bed *(typically 18 inches).* This method, and knowledge of the approximate depth and configuration of the facility, may then be used to develop stage-discharge and stage-storage relationships that are used to size the facility.

1. Basic sand filtration systems should be designed to capture and treat specific volume of runoff from the water quality design storm (see chapter 2). This can be achieved by using a diversion structure (i.e., isolation/diversion baffles and weirs, Figures 5.14 and 5.15). The diversion structure should be able to divert the first portion of runoff (i.e., first ~~½-inch) from the designed storm and~~ No pass the remaining runoff to the ~~creek or floodwater~~ detention system. The structure must be capable of diverting and passing flows during the entire storm. The outflow from sand filtration basin, however, is generally controlled by Darcy's Equation as specified above.

2. For a basic sand filter a design hydraulic conductivity of *one (1) inch/hour* should be used and the filter should be sized to completely empty (drawdown time) the design storm volume in 24 hours or less (alternative: 24 hours drawdown from presettling chamber and 24-40 hours from sand filtration basin). Water depth above the filter should be no more than 6 feet (4).

A minimum of one foot of freeboard for both presettling chamber and filtration basin, and an overflow bypass structure for the filtration basin are recommended (water in filtration basin may spill when consecutive storms occurred or when sand bed is somehow clogged)

3. For a large sand filter the sediment or presettling chamber should be sized to capture all runoff designated to enter the filter system. Under normal conditions, the sand bed should have a hydraulic conductivity of 1.50 inch/hour.

4. The following layers are suggested: top layer-sand, 2rd-geotextile, and 3th-underdrain system. (4).

5. Runoff discharging to the sand filter ~~should~~ must be pretreated (e.g., presettling basin, etc. depending on pollutants) to remove debris, gross solids, and oil and grease from high use sites. ~~The length to width ratio of the presettling basin should be 3:1 and~~ The depth of water in the presettling chamber should be about 3-6 feet (4). {comment: if inlet structure exists, and energy dissipation devices are installed the "3:1" L:W ratio may not be needed}.

6. Inlet structures associated with the diversion structure (e.g., flow spreaders; weirs or multiple orifice openings) should be designed to capture the first ½-inch (or specific volume of) runoff, minimize turbulence, and spread the flow uniformly across the surface of the filter media.

7. Stone rip rap or other and energy dissipation devices should ~~also~~ be installed to prevent gouging of the sand media and to promote uniform flow (see Figure 5.10). ~~Off-line outlet structures should be sized for the 15 min. peak flow of a 2 year 24-hour storm. (4)~~

8. The following are design criteria for underdrain piping:

- Types of underdrains: a central collector pipe with lateral feeder pipes, or, with a geotextile drain strip in an 8 inch gravel backfill or drain rock bed, or, a longitudinal pipes in an 8-inch gravel backfill or drain rock with a collector pipe at the outlet end.

- ~~Hydraulically it should be sized for the 15 minute peak flow from a 2 year 24 hour storm, with one (1) foot of head above the invert of upstream end of the collector pipe (4).~~

Ponding level
s- discharge

(Comment: Outflow is controlled by Darcy's equation)

- Internal diameters of underdrain pipes should be a minimum of six (6) inches and 2 rows of ½ inch holes spaced 6 inches apart longitudinally (maximun 6 inches), with rows 120 degrees apart (laid with holes downward). Maximum perpendicular distance between two feeder pipes must be 10 feet (6). All piping is to be schedule 40 PVC or greater wall thickness.

- Main collector underdrain pipe should be at a slope of 0.5% minimum (4)

- A geotextile fabric (specifications in App. B-Vol. V) must be used between the sand layer and drain rock or gravel and placed so that one-inch of drain rock/gravel is above the fabric. Drain rock should be 1.5 to .75 inch rock or gravel backfill, washed free of clay and organic material (4)

- Cleanout wyes with caps or junction boxes must be provided at both ends of the collector pipes. Cleanouts must extend to the surface of the filter. A valve box must be provided for access to the cleanouts. (See Figures 5.11 & 5.13)

9. Sand specification: The sand in a filter must consist of a medium sand meeting the size gradation (by weight) given in Table 5.3 below. The contractor must obtain a grain size analysis from the supplier to certify that the No. 100 and No. 200 sieve requirements are met. *(Note: Standard backfill for sand drains, Wa. Std. Spec. 9-03.13, does not meet this specification and should not be used for sand filters.)*

Spec similar to the ASCE Spec

Table 5.3 -- Sand Medium Specification

U.S. Sieve Number	Percent Passing
4	95-100
8	70-100
16	40-90
30	25-75
50	2-25
100	<4
200	<2

Source: King County Surface Water Design Manual, September 1998

10. Impermeable Liners for Sand Bed Bottom

    Impermeable liners are generally required for non-conventional soluble pollutants such as metals and organics and where the underflow could cause problems with structures. Impermeable liners may be clay, concrete or geomembrane. Clay liners should have a minimum thickness of 12 inches and meet the specifications give in Table 5.4:

Table 5.4 -- Clay Liner Specifications

Property	**Test Method**	**Unit**	**Specification**
Permeability	ASTM D-2434	cm/sec	$1 \times 10^{-6\ max.}$
Plasticity Index of Clay	ASTM D-423 & D-424	percent	Not less than 15
Liquid Limit of Clay	ASTM D-2216	percent	Not less than 30
Clay Particles Passing	ASTM D-422	percent	Not less than 30
Clay Compaction	ASTM D-2216	percent	95% of Standard Proctor Density

Source: City of Austin, 1988

11. If a geomembrane liner is used it should have a minimum thickness of 30 mils and be ultraviolet resistant. The geomembrane liner should be protected from puncture, tearing, and abrasion by installing geotextile fabric (see Vol. V-App. B) on the top and bottom of the geomembrane.

12. Concrete liners may also be used for sedimentation chambers and for sedimentation and filtration basins less than 1,000 square feet in area. Concrete should be 5 inches thick Class A or better and should be reinforced by steel wire mesh. The steel wire mesh should be 6 gauge wire or larger and 6 inch by 6 inch mesh or smaller. An "Ordinary Surface Finish" is required. When the underlying soil is clay or has an unconfined compressive strength of 0.25 ton per square foot or less, the concrete should have a minimum 6 inch compacted aggregate base. This base must consist of coarse sand and river stone, crushed stone or equivalent with diameter of 0.75 to 1 inch.

13. If an impermeable liner is not required then a geotextile fabric liner should be installed that retains the media and meets the specifications listed below in Volume V-App. B unless the basin has been excavated to bedrock.

14. If an impermeable liner is not provided, then an analysis should be made of possible adverse effects of seepage zones on ground water, and near building foundations, basements, roads, parking lots and sloping sites. Sand filters without impermeable liners should not be built on fill sites and should be located at least 20-ft downslope and 100 ft upslope from building foundations.

15. Include an access ramp with a slope not to exceed 7:1, or equivalent, for maintenance purposes at the inlet and the outlet of a surface filter.

16. Side slopes for earthen/grass embankments should not exceed 3:1 to facilitate mowing.

17. Disturbed areas that are sediment sources in the contributing drainage area should be identified and stabilized to the maximum extent practicable. Because of the potential for clogging, sand filtration BMPs must never be used as sediment basins during construction unless the entire sand bed, as well as the underdrain system, is renewed after the site is stabilized.

18. High groundwater may damage underground structures or affect the performance of filter underdrain systems. There should be sufficient clearance (at least 2 feet is recommended) between the seasonal high groundwater level (highest level of ground water observed) and the bottom of the BMP to obtain adequate drainage.

5.3.1 General Construction/ Maintenance Criteria- Sand Filter BMPs

No runoff should enter the sand filter prior to completion of construction and approval of site stabilization by the responsible inspector. Construction runoff may be routed to pretreatment sedimentation BMPs, but discharge from these BMPs should by-pass downstream sand filters.

- Careful level placement of the sand is necessary to avoid formation of voids within the sand that could lead to short-circuiting, (particularly around penetrations for underdrain cleanouts) and to prevent damage to the underlying geomembranes and underdrain system. Voids between the trench walls and the geotextile fabric should also be avoided.
- Over-compaction should be avoided to ensure adequate filtration capacity. Sand is best placed with a low ground pressure bulldozer (4 psig or less)
- After the sand layer is placed water settling is recommended. Flood the sand with 10-15 gallons of water per cubic foot of sand.

Maintenance Criteria

Inspections of filters and pretreatment systems should be conducted every 6 months and after storm events as needed during the first year of operation, and annually thereafter if filter performs as designed. Maintenance agreement should be established at the time of permitting to ensure that annual maintenance is scheduled. Repairs should be performed as necessary.

- Accumulated silt, and debris on top of the filter media should be removed when their depth exceeds 1/4 inch. The silt should be scraped off during dry periods with steel rakes or other devices. Once sediment is removed, the design permeability of the filtration media can typically be restored by then striating the surface layer of the media. Finer sediments that have penetrated deeper into the filtration media can reduce the permeability to unacceptable levels, necessitating replacement of some or all of the sand.
- Media replacement frequency is not well established and will depend on suspended solids levels entering the filter (the effectiveness of the pretreatment BMP can be a significant factor). Drainages with disturbed areas containing clay soils will likely necessitate more frequent media replacement. Remove debris and sediment from the pretreatment facility when the depth exceeds 12 inches.

- Frequent overflow through the grated "birdcage" window into the outlet structure or slow drawdown are indicators of plugging problems. A sand filter should empty in 24-40 hours or less following a storm event (24 hours for presettling chamber), depending on pond depth. If drawdown time increases significantly, corrective action is needed, e.g.: 3:2 TAC

    - Scraping the top layer of fine-grain sediment accumulation (mid-winter scraping is suggested)
    - Removal of thatch
    - Aerating the filter surface
    - Tilling the filter surface (late-summer rototilling is suggested)
    - Replacing the top 4-6 inches of grass and sand.
    - Inspecting geotextiles for clogging

- Rapid drawdown in the sand bed (greater than 12 inches per hour) indicates short-circuiting of the filter. Inspect the cleanouts on the underdrain pipes and along the base of the embankment for leakage.

- Drawdown tests for sand bed could be conducted, as needed, during the wet season. These tests can be conducted by allowing the filter to fill (or partially fill) during a storm event, then measuring the decline in water level over a 4-8 hour period. Blocking of inlet and underdrain outlet would be necessary in order to conduct such a test.

- Formation of rills and gullies on the surface of the filter indicates improper function of the inlet flow spreader, or poor sand compaction. Check for accumulation of debris on or in the flow spreader and refill rills and gullies with sand.

- Access for cleaning all underdrain piping should be provided. This may consist of installing cleanout ports, which tee into the underdrain system and surface above the top of the sand filtration media.

- To facilitate maintenance of the sand filter during inlet flow conditions an inlet shutoff/bypass valve is recommended

- Avoid using excess fertilizers, and driving heavy equipment on the filter to prevent compaction and rut formation.

BMP T5.50 Sand Filtration Basins[6]

Sand filtration basins are open impoundments, which filter runoff into an underdrain system through a layer of sand.

Additional Design Criteria for Sand Filtration Basins:

1. A minimum sand bed depth of 18 inches is recommended (See Table 2 for sand specifications). This is the final bed depth, which includes consolidation of the sand during construction. Two sand bed configurations can be selected: one with a gravel layer and the other using a trench design with drainage matting instead of the gravel layer. The surface sand layer should be level so that equal distribution of runoff will be achieved in the basin.

   a. *Sand Bed with Gravel Layer (Figure 5.17)*

      Under the sand should be a layer of ½ to 2 inch diameter gravel which provides a minimum of 8 inches of cover over the top of the underdrain lateral pipes. No gravel is required under the lateral pipes. The sand and gravel must be separated by a layer of geotextile fabric meeting the specifications listed in Vol. V-App. B. OK

   b. *Sand Bed with Trench Design (Figure 5.18)*

      This configuration can be used on flatter sites, which may restrict the applicability of the previous design. The depth of the top layer should be a minimum 12-18 inches (12 inches to the gravel layer, 18 inches to the trench bottom). Laterals should be ~~placed in~~ trenches with a covering of ½ to 2 inch gravel and geotextile fabric. The lateral pipes should be underlain by a layer of drainage matting. The geotextile prevents the filter media from infiltrating into the lateral piping and the drainage matting provides adequate hydraulic conductivity to the laterals. Vol.V-App. B provides specifications for geotextile fabric and for drainage matting. OK

2. Spacing between laterals depends on the size of sand bed but it should never exceed 10 feet. The maximum spacing between rows of perforations should be 6 inches. The minimum grade for laterals should be 0.5 % slope.

3. Maintenance vehicle access (ramp slope should not exceed 4:1 for basins) is necessary.

4. Side slope for earthen embankments should not exceed 3:1 to facilitate mowing.

BMP T5.60 - Sand Filter Vaults[4,6]

Description: (Figures 5.19)

A sand filter vault is similar to an open sand filter except that the sand layer and underdrains are installed below grade in a vault. It consists of presettling and sand filtration cells.

Applications and limitations:

- Use where space limitations preclude above ground facilities
- Not suitable where high water table and heavy sediment loads are expected
- An elevation difference of 4 feet between inlet and outlet is needed

Additional Design Criteria

Sand filter criteria apply in addition to the following specific criteria recommended for vaults:

- Vaults should be designed as off-line systems.
- A third chamber or a diversion structure should be installed to divert the first portion of runoff (e.g., ½-inch) into sediment chamber and pass the remaining runoff to the creek (excess runoff will re-suspend sediments in the presettling chamber (permanent pool).
- Optimize inlet flow distribution with minimal sand bed disturbance. A maximum of 8-inch distance between the top of the spreader and the top of the sand bed is suggested. Flows may enter the sand bed by spilling over the top of the wall into a flow spreader pad or alternatively a pipe and manifold system may be used. Any pipe and manifold system must retain the required dead storage volume in the first cell, minimize turbulence, and be readily maintainable.
- If a pipe and manifold system is used, the minimum pipe size should be 8 inches. Multiple inlets are recommended to minimize turbulence and reduce local flow velocities.
- Erosion protection must be provided along the first foot of the sand bed adjacent to the spreader. Geotextile fabric secured on the surface of the sand bed, or equivalent method, may be used.
- The filter bed should consist of a sand top layer, and a geotextile fabric second layer with an underdrain system.

- If a presettling cell is used it should be designed for sediment collection and removal. A V-shaped bottom, removable bottom panels, or equivalent sludge handling system should be used.
- One foot of sediment storage in the presettling cell must be provided.
- The presettling chamber should be sealed to trap oil and trash. This chamber is usually connected to the sand filtration chamber through an invert elbow. This connection keeps the filter surface from oil and trash.
- A non-porous, non-shrinking grout, or equivalent, must be used to seal all piping joints that convey stormwater in the system.
- If a retaining baffle is necessary for oil/floatables in the presettling cell, must extend at least one foot above to one foot below the design flow water level, and be spaced a minimum of 5 feet horizontally from the inlet. Provision for the passage of flows in the event of plugging must be provided. Access opening and ladder must be provided on both sides of the baffle.
- Provision for access is the same as for wet vaults
- Sand filter vaults must conform to the materials and structural suitability criteria specified in the wet vault section of Chapter 6.

Design Recommendation A dewatering gate valve just above the sand bed.

- A geotextile fabric over the entire sand bed that is flexible, highly permeable, three-dimensional matrix, and adequately secured. This is useful in trapping trash and litter.
- Increasing the grate area for more air contact with the sand bed

Maintenance Criteria for Vaults Removable panels must be provided over the entire sand bed. Panels must be at grade, have stainless steel lifting rings, and weigh no more than 5 tons each.

- To prevent anoxic conditions, a minimum of 24 square feet of ventilation grate must be provided for each 250 square feet of sand bed surface area. For sufficient distribution of air flow across the sand bed, grates may be located in one area if the sand filter is small, but placement at each end is preferred. Small grates may also be dispersed over the entire sand be area.

BMP T5.70 - Linear Sand Filters[4]

***Description:* (*Figure 5.20*)**

Linear sand filters are typically long, shallow, two-celled, rectangular vaults. The first cell is designed for settling coarse particles, and the second cell contains the sand bed. Stormwater flows into the second cell via a weir section that also functions as a flow spreader.

Application and limitations

Applicable in long narrow spaces such as the perimeter of a paved surface

- As a part of a treatment train as downstream of a filter strip, upstream of an infiltration system, or upstream of a wet pond or a biofilter for oil control
- To treat small drainages ~~(less than 5 acres)~~ (less than 2-acre of impervious area)
- To treat runoff from high-use sites for TSS and oil/grease removal, if applicable

Design Criteria

Sand filter criteria apply in addition to the following specific criteria recommended for linear sand filters:

- Unless a diversion structure (third chamber) is installed, linear filter should treat a very small area such that the presettling chamber can capture runoffs from most storms.
- The two cells should be divided by a divider wall that is level and extends a maximum of 12 inches above the sand bed
- Stormwater may enter the sediment cell by sheet flow or a piped inlet
- The width of the sand cell must be 1-foot min. to 15 feet max.
- The sand filter bed must be a minimum of 18 inches deep and have an 8-inch layer of drain rock with perforated drainpipe beneath the sand layer.
- The drainpipe must be 6 inch diameter min. and be wrapped in geotextile and sloped a minimum of 0.5%
- Maximum sand bed ponding depth is 1 foot
- Must have an emergency overflow route, either surface overland, tightline, or other structure for safely controlling the overflow.

- Linear sand filters must conform to the materials and structural suitability criteria specified in the wet vault section of Chapter 6.

Set sediment cell width as follows:

Sand filter width, w, feet	1-2	2-4	4-6	6+
Sediment cell width, in.	12	18	24	w/3

Figure 5.10 Basic Sand Filtration Basin System

Figure 5.11. Sand Filter with Pretreatment Cell (also considered as basic filter)

~~Figure 5.11. Sand Filtration Basin Preceded by Presettling Basin~~

Figure 5.12 Sand Filtration Basin Preceded by sediment chamber
(large sand filter, variation of basic sand filter)

~~Figure 5.12 Example Isolation/Diversion Structure~~

Figure 5.13. Sand Filter with Level Spreader (another variation of basic filter)

~~Figure 5.13 Example Isolation/Diversion Structure~~

Figure 5.14. Example Flow Splitter/Diversion Structure

~~Figure 5.14 Sand Filter with Level Spreader~~

Figure 5.15. Example Flow Splitter/Diversion and Flow Spreader Structure

~~Figure 5.15 Sand Filter with Level Spreader (continued)~~

Figure 5-16. Orifice Control and Flow Spreader Devices (new drawing added)

~~Figure 5.16 Sand Filter with Pretreatment Cell~~

Figure 5.17 Sand Bed Profile with Gravel Layer

Figure 5.18 Sand Bed Profile with Trench Design

Figure 5.19 Sand Filter Vault

~~Figure 5.20 Sand Filter Vault (continued)~~

Figure 5.20 Linear Sand Filter

~~Figure 5.21 Linear Sand Filter~~